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THE ECLIPSING VARIABLE θ^1 ORIONIS A IN THE TRAPEZIUM

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In January-February 1976, the authors conducted photoelectric UBVR observations of θ^1 Ori A and obtained 33 estimates in each filter. The observations covered the principal maximum of θ^1 Ori A and the phases outside the eclipse. The amplitude of brightness changes of θ^1 Ori A was at a maximum at U ($1\overset{m}{.}02$) and at a minimum at ($0\overset{m}{.}82$), which is not in agreement with Lohsen's determinations.

By the Russell-Merrill method (x = 6.5), three brightness curves of θ^1 Ori A in system V constructed from all the existing observations were solved. The results obtained could not be unambiguously determined. Possibly, the dark binary systems θ^1 Ori A and BM Ori are related objects.

Introduction. The variability of θ^1 Ori A was detected by Lohsen (1975) during electrophotometric observations of BM Ori with a stellar scanner. Lohsen's discovery was confirmed by other observers (Strand, 1975; Feibelman, 1975a, b, etc.).

Baldwin (1976) was able to establish that the period of θ^1 Ori A was one-third as long as had been determined earlier by other authors (Lohsen, 1975; Strand, 1975). At the present time, the light elements of θ^1 Ori A can be represented by the following quantities:

$$Min_{\odot} = 2441966.826 + 65^{d}.4325 \cdot E,$$

where the initial epoch is taken from Strand's determination (1975), and the period is taken from the observations of Franz (1977). Lohsen (1975) determined that the amplitude of brightness changes of θ^1 Ori in the system UBV is identical in all the filters and is equal to $1^{m}.04$. Photoelectric observations of the anticipated secondary minimum of θ^1 Ori A (Walker, 1976a) did not show attenuation of the system brightness, since the ephemerides of the minimum was calculated with the initial period ($P = 196^{d}.297$). From Baldwin's visual estimates (1976), the secondary minimum of θ^1 Ori A was not detected.

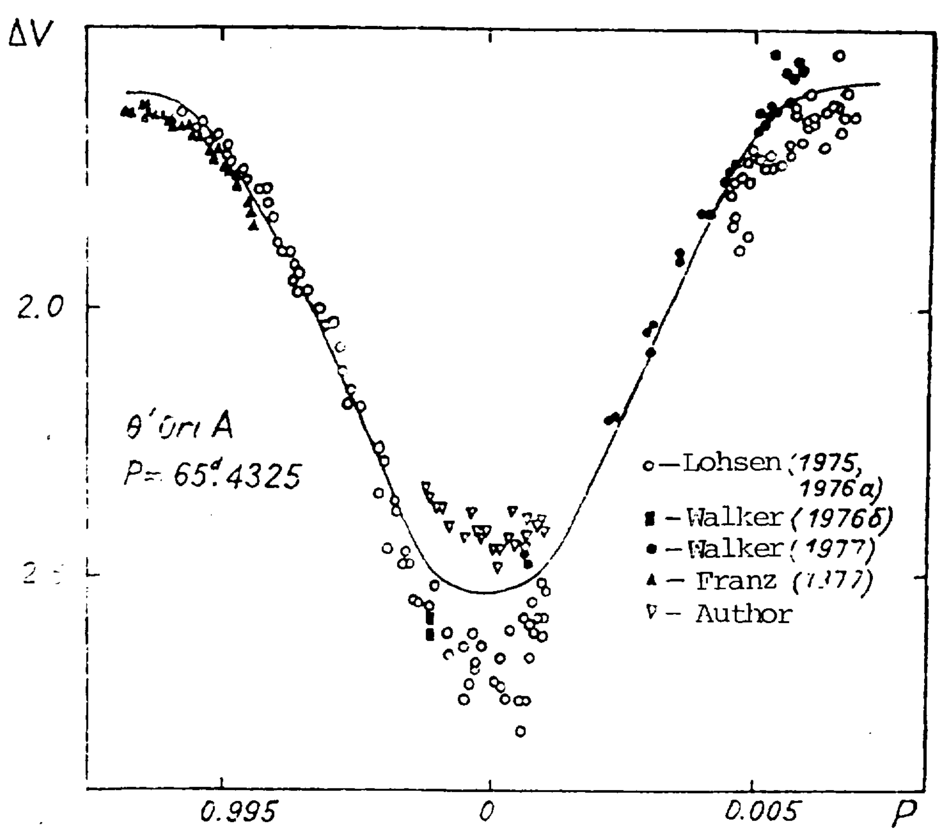
Observations. In January-February 1978, photoelectric observations were made of θ^1 Ori A in the UBVR system using the 40-cm reflector of the High-Altitude Maydanak Expedition of the Astronomical Institute of the Uzbek SSR Academy of Sciences (Zakirov, 1978). The observations were made with a working diaphragm 11"±1" and a light flux accumulation time of 5 s. To reduce the observational errors, the background was taken into account by a method described by Hall and Garrison (1969). Stars in the Trapezium θ^1 Ori C and D served as the reference stars. The random error of one stellar brightness measurement proved to be approximately identical in all filters and was equal to $\pm 0\overset{m}{.}02$. The observations covered the principal maximum of θ^1 Ori A and measurements outside the eclipse were recorded. The results are given in the table at the end of the article.

The amplitude of the changes of θ^1 Ori A in U was $1\overset{m}{.}02$; in B, $0\overset{m}{.}95$; in V, $0\overset{m}{.}93$; and in R, $0\overset{m}{.}82$ with a root-mean-square error less than $0\overset{m}{.}01$. It was not possible to interpret these results as the possible secondary minimum of θ^1 Ori A with the period presented above. Possibly, this difference in the magnitude of the amplitude of θ^1 Ori A from Lohsen's determinations (1975) was due to the method of allowing for the nebular background and to the differences in the photometric systems. Two brightness determinations at the minimum of θ^1 Ori A, performed by Walker (1977), are in good agreement with our measurements. Shown in the figure is the minimum of θ^1 Ori A with respect to all the observations processed with the above-presented light elements.

Solution of brightness curve. The brightness curve of θ^1 Ori A was solved by Lohsen (1976a) with a period of $365\overset{d}{.}15$, which is six times greater than its present-day value. In order to study representative characteristics of the binary system of θ^1 Ori A, three brightness curves were solved (averaged curve from the observations of all authors, a curve from the experiments of Lohsen and Franz, and a curve from the observations of Walker and the present author) by the Russell-Merrill method with a darkening coefficient at the limb $x = 0.5$. At the minimum of θ^1 Ori A, a constant-brightness period

At the minimum of θ^1 Ori A, a constant-brightness period $d = 2^h_{\cdot} \pm 1^h$ was observed (Lohsen, 1976a); from our observations, $d = 1^h_{\cdot}5$. The solutions of the brightness curves were made on the hypothesis that Б → M and that the minimum corresponds to total eclipse. Rectification of the brightness curves for the effect of reflection and ellipsoidality of the system components could not be carried out in view of the lack of observational data. The system orbit was assumed to be circular. The photometric elements of θ^1 Ori that were obtained from the three brightness curves in the system V were averaged and are presented below:

r_s	r_g	i	L_s
0.014±0.001	0.029±0.002	88°.9±0°.3	0.58±0.03



obtained from a solution of the averaged brightness curve based on the observations of all authors is shown by the solid line.

Discussion of results. The less bright component of the binary system has a larger radius than the brighter component. The visible magnitudes of the components m_1 = 7.23 V and m_2 = 7.56 V. The brighter component will be assumed to be the principal star of the system. Light absorption for the stars in the Trapezium $A_V = 1^m8$ (Lee, 1968), while the absolute magnitudes of the components M_{V_1} = 02.6 and M_{V_2} = -2.2 (m - M = 8.0). The components of the system in terms of luminosity corresponded to the stars B2V and B2.5V. θ' Ori A is in the spectral class $B0.5V_p$ (Petrie, 1965). The luminosity deficit for the principal component in this case is $1^m.2$V. We note that an analogous situation obtains also in the case Bm Ori (Hall and Garrison, 1969). On a two-color plot $(U - B)_0$ versus $(B - V)_0$, the components are classified as the stars B1 and B2. The components of θ' Ori A in terms of luminosity even on the two-color plot correspond to the stars B1-2V and B2-2.5V. The stars in the spectral class B1-2V ($\mathfrak{M} = 10\mathfrak{M}_\odot$) attain the ZAMS* during a period of the order of 10^5 years (Iben, 1965), therefore it is not clear why the satellite has twice the radius as the principal star. To explain this contradiction, it can be assumed that either the hypothesis $Б \rightarrow M$ is invalid and that the inverse hypothesis

* ZAMS: Zero Age Main Sequence--ed.

($M \to б$) obtains, or the satellite has a shape of a highly flattened ellipsoid, as in the case of BM Ori (for example, Popper, Plavets, 1976). In favor of the latter hypothesis we can point out that a marked secondary minimum of θ' Ori A has not been observed (Baldwin, 1976). If we consider the estimate of the masses of the θ' Ori A components made by Lohsen (1976b), then in the case of a circular orbit they correspond to the stars B1.5V and B8V. Then in order to explain satisfactorily the depth of the minimum, we must assume $r_s/r_g = 0.8$ (underlying the calculations was the hypothesis $M \to б$ and $x = 0.5$). By considering the principal star of θ' Ori A as belonging to ΓII, we can find the satellite radius to be 1.5 times larger than for the star B8V. A star in the spectral class B8V ($\mathfrak{M} = 5\mathfrak{M}_{\odot}$) attains the ZAMS in a time period of the order of $6 \cdot 10^5$ years (Iben, 1965), which is greater than the age of the Trapezium (10^4 to $3 \cdot 10^5$ years).

Thus, it can be proposed that the satellite of θ' Ori A is in the stage of evolution to ZAMS; we do not exclude the possibility that the eclipsing variables θ' Ori A and BM Ori can be related objects. Further photoelectric (especially of the secondary minimum) and spectral observations are needed to clarify the nature of θ' Ori A.

TABLE

JD⊙	A−C ΔU	ΔB	ΔV	ΔR	JD⊙	A−C ΔU	ΔB	ΔV	ΔR
2443500+					2443500+				
37.1250	$+2^{m}.53$	$+2^{m}.30$	$+2^{m}.34$	$+2^{m}.36$	37.2521	$+2^{m}.64$	$+2^{m}.42$	$+2^{m}.41$	$+2^{m}.29$
.1285	2.55	2.32	2.36	2.25	.2591	2.64	2.42	2.42	2.36
.1368	2.56	2.32	2.37	2.29	.2639	2.64	2.42	2.43	2.40
.1424	2.62	2.34	2.37	2.37	.2667	2.65	2.42	2.41	2.40
.1611	2.64	2.41	2.39	2.32	47.0863	1.66	1.49	1.50	1.54
.1799	2.62	2.39	2.38	2.30	.1474	1.68	1.48	1.49	1.50
.1827	2.67	2.42	2.42	2.35	.1565	1.66	1.50	1.48	1.52
.1910	2.68	2.41	2.41	2.33	.1641	1.67	1.48	1.47	1.51
.1933	2.70	2.44	2.42	2.36	.1697	1.70	1.47	1.46	1.50
.2063	2.67	2.41	2.41	2.32	49.1111	1.68	1.50	1.53	1.52
.2162	2.70	2.43	2.44	2.34	.1722	1.67	1.49	1.50	1.53
.2181	2.70	2.43	2.46	2.34	55.1183	1.64	1.48	1.49	1.50
.2216	2.69	2.44	2.48	2.36	.1738	1.67	1.49	1.49	1.55
.2264	2.70	2.44	2.43	2.34	.1808	1.65	1.47	1.49	1.50
.2354	2.69	2.44	2.43	2.35	56.1501	1.67	1.48	1.52	1.52
.2417	2.67	2.42	2.38	2.32	.1578	1.69	1.42	1.54	1.53
.2479	2.70	2.46	2.44	2.39					

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